DEMOGRAPHY (Chapter 12, pages 273-295)

Session Objectives

- Understand the basic concepts of using demographic information for population viability analysis.
- Understand the challenges of using demographic methods for monitoring plants.

I. Introduction

A. Definition: "Demography deals with the quantitative aspects of birth, growth, reproduction, and death in a population" (Solbrig 1980).

B. Demographic monitoring is typically used to perform population viability analysis (PVA).

1. Approach has become very popular, particularly in last couple of decades. Has been used not just for rare species; some powerful studies have been done on weeds and native species that are not rare.
2. Good recent publications by Morris et al. (1999) and Morris and Doak (2002) explain PVA in a manner that is not too technical. The Morris et al. (1999) publication is provided to you on CD.

C. Basic concept.

1. A human example (**Figure 12.1**).

Demographic approach		Number of individuals			
		Old Time Fiddlers; Aspen, CO		Old Time Fiddlers; Picabo, ID	
none		150		150	
by sex		Male	Female	Male	Female
		70	80	5	145
by sex and by age	0 - 5	6	8		
	6 - 12	8	7		
	13 - 18	14	17		1
	19 - 27	16	22		2
	28 - 45	13	19		26
	46 - 60	9	6		45
	61 - 75	3	1	3	52
	> 75	1	0	2	19

FIGURE 12.1. Summary of two populations of Old Time Fiddlers. While the size of the groups is identical, the demographic distribution of the two groups differs dramatically. The likely fate of the two groups is also quite different.

2. A plant example: stage classes and environmental influences (**Figure 4.2**).

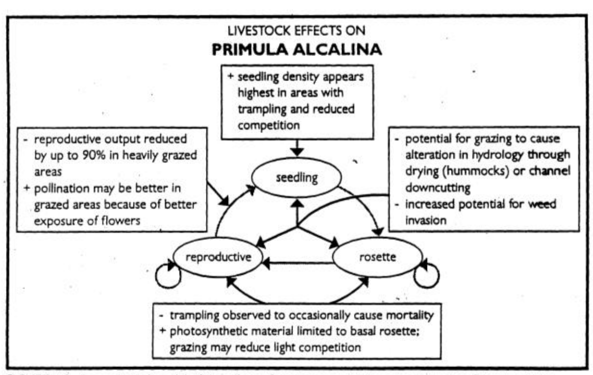

FIGURE 4.2. An ecological model of the effects of grazing on an Idaho endemic species, Primula alcalina.

3. Three types of demographic approaches:
    a) Population modeling and viability analysis.
    b) Single age/stage class investigations.
    c) Demographic structure.
4. There is also a PVA procedure based on simple counts.

II. Population modeling and PVA
  A. Understanding transitions.
    1. Identify stage classes.
    2. Develop a model of transitions.
      a) Example: Simple life history and transition matrix (**Figure 12.2**).
        (1) Three stages.
        (2) Monitoring is focused on estimating transition probabilities.

	FROM:		
TO:	**seedling**	**rosette**	**flowering**
seedling	0.00	0.00	60.00
rosette	0.10	0.25	.20
flowering	0.01	0.15	.45

Figure 12.2

      b) Example: Short-lived perennial (**Figure 12.6**).

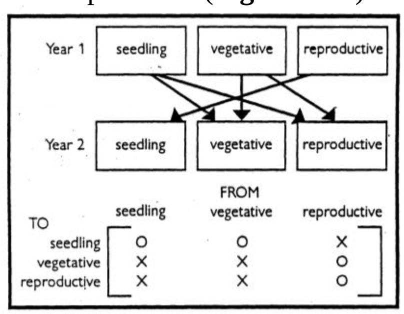

FIGURE 12.6.

      c) Example: Perennial with a seed bank that lasts three years (**Figure 12.7**).

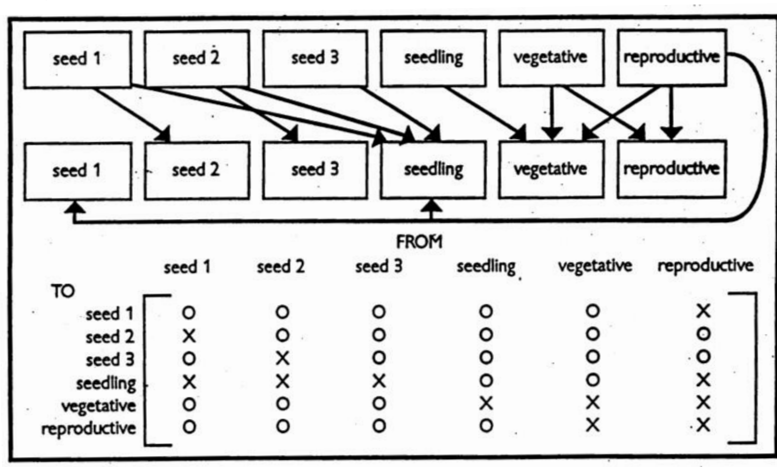

FIGURE 12.7.

B. Using transition matrices to estimate population parameters.
   1. TR introduces the procedure (pages 276-279).
   2. Software available to calculate the population parameters for you.
      a) RAMAS/stage the most important "off-the-shelf" software for plants.
   3. The two important population parameters:
      a) Lambda (λ) is the most important.
         (1) It's the finite rate of population increase.
         (2) $\lambda > 1.0$ represents a population that is increasing – the larger the λ value the faster that population is increasing.
         (3) $\lambda = 1.0$ represents a population that is stable.
         (4) $\lambda < 1.0$ represents a population that is declining.
      b) Elasticity matrix.
         (1) Elasticity values are a measure of the sensitivity of the population growth rate to a change in transition probabilities.
         (2) Changes in transition probabilities for transitions with high elasticity values will result in a greater change in the overall lambda value than a similar change in probability for a transition with a low elasticity value.
         (3) Elasticity values can identify which stages and transitions should be managed to provide the largest overall population benefits (**Table 9.1 from Morris and Doak 2002**).

TABLE 9.1 Estimated current values, sensitivities, and elasticities for vital rates of the emperor goose[a]

Vital rate	*Estimated value*	*Sensitivity*	*Elasticity*
s_0, survival of zero-year-olds[b]	0.1357	0.58	0.080
$s_{\geq 1}$, survival of one-year-old and older birds	0.8926	1.02	0.92
f_2, reproduction of two-year-olds[c]	0.6388	0.0088	0.0057
$f_{\geq 3}$, reproduction of three-year-old and older birds	0.8943	0.082	0.074

From:
Morris, W. F., and D. F. Doak. 2002. Quantitative conservation biology: theory and practice of population viability analysis. Sinauer Associates Inc., Sunderland, MA.

Because the elasticity value for the survival of one-year-old and older birds is much higher than those for the other three vital rates, increasing the survival of one-year-old and older birds will have a much greater effect on increasing lambda than increasing any of the other three vital rates. The footnotes, which are not reproduced here, refer to the source of the data and how Morris and Doak used those data in this table.

C. Population Viability Analysis.
   1. Because no population or species is completely free from the risk of extinction, viability is a probabilistic concept, not an absolute one.
      a) Concept of viability requires both a probability and a time frame.
      b) For example, an objective could be "Population Y of Species X should have a 95% chance of persisting to the year 2100."
   2. Demographic modeling is the most powerful tool for measuring the viability of a population.

3. Let’s say we’ve measured 3 transitions for a population (3 years, 3 transition matrices).
    a) One year was a “bad” year, with a lambda value of 0.35 (lots of mortality from drought).
    b) One year was average, with a lambda value of 1.00.
    c) One year was a “good” year, with a lambda value of 1.76.
4. A computer can choose matrices at random from these three years and calculate and project the population size through time to the year 500.
    a) If, by chance, the computer uses data representing many bad years in a row, the population may crash after only a few years.
    b) If, on the other hand, the computer chooses data representing many good years in a row, the population may survive to year 500 and even grow.
5. By doing a large number of these simulations, a frequency distribution is generated of the time to extinction for your population.

6. **Figure 12.4** illustrates the probability of extinction in any one year, as well as the cumulative probability of extinction.

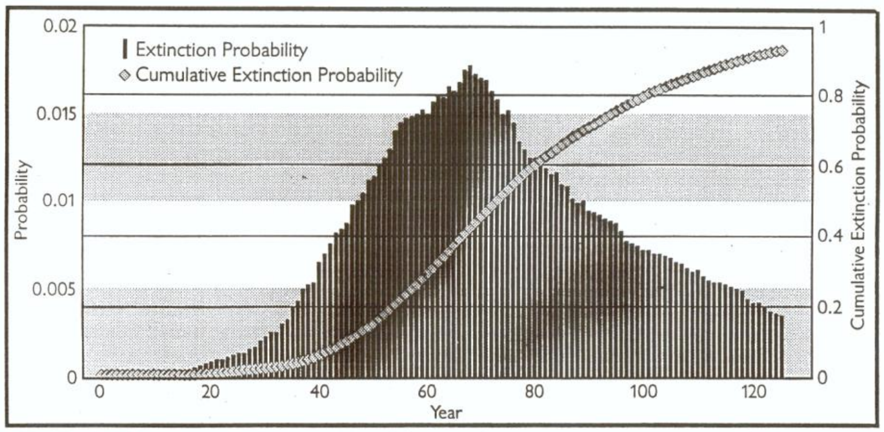

FIGURE 12.4. Extinction probabilities calculated from simulation using measured transitions. The long "tail" on the right indicates rare simulated successes, or survival, to the end of the simulation period. The majority of extinctions in this simulation, however, occur before 120 years have passed, as illustrated by the cumulative extinction probability.

7. The cumulative probability that the species will become extinct in 100 years is 80.1%.

D. If annual variation is thought to be due largely to weather patterns, you can increase the biological realism of your simulations by matching transitions with long-term weather records. The number of times a given matrix or stage is used in a simulation can be dictated by the number of times a similar weather year arises in the weather record.

III. Field Techniques
- A. Must mark and/or map individuals (see TR, pages 281-282).
- B. Must choose clearly identifiable stage classes (or, for some plants, size classes may be appropriate).
- C. Must pay attention to the timing of monitoring.
- D. Sampling considerations.

IV. Challenges
   A. Certain life forms.
      1. Annuals.
         a) Adequate models can't be constructed without factoring in seed bank dynamics (see Doak et al. 2002).
         b) Must know the age structure of the seed bank.
         c) Even if something is known about seed bank dynamics, models don't adequately consider infrequent "rescue" episodes from the seed bank.
      2. Geophytes and plants with dormant phase – difficult to measure hidden phases.
      3. Rhizomatous growth forms – difficult or impossible to use demographic techniques because there is no consistent measuring unit.
   B. Variability in time.
      1. This approach *projects* the results of your measurements into the future, it does not *predict*.
         a) Thus, if the results from the years you monitored are atypical of the results you would get in future years, the viability analysis can be very wrong.
         b) **Figure 12.11** illustrates this. Also refer to the paper by Bierzychudek (1999; provided on CD) who revisited two populations of jack-in-the-pulpit 15 years after she conducted a classic demographic study (Bierzychudek 1982). She found that while one of the populations changed as her model projected it would, the other one did not: her model had projected the population would increase but it actually decreased.

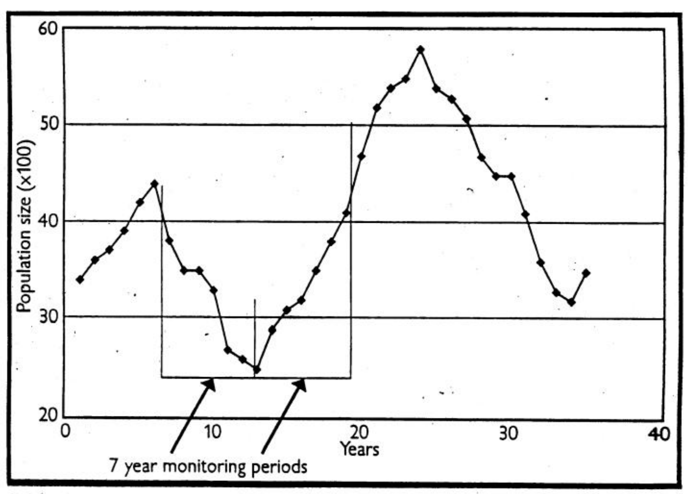

FIGURE 12.11. This diagram shows a population with naturally fluctuating numbers. Note how different projections and conclusions would be based on the first monitoring period compared to the second.

         c) Measuring transitions through as many years as possible reduces this problem (Morris et al. 1999 recommend at least 6 years), but also increases the expense of the monitoring.
      2. Stochastic events are important, but difficult to model.

3. Lambda values have sampling error associated with them, but few published studies have included an estimate of this error.

C. Variability in space.

1. Many demographic studies have measured plants in subjectively located plots.
2. This approach fails to incorporate the spatial variability in a population (**Figure 12.12**).

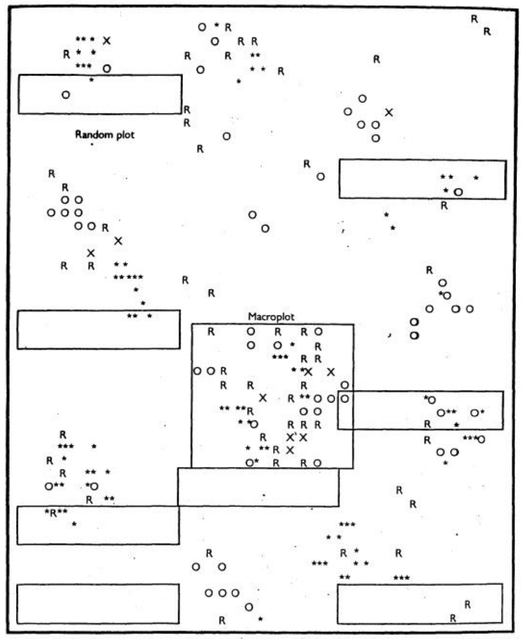

FIGURE 12.12. Population is represented by nonreproductive individuals (O), reproductive individuals (R), seedlings (*), and dead individuals (X). Population structure varies in space. A macroplot approach is positioned the plot in the densest portion of the population. An alternative approach is to use randomly located sampling units.

D. Dealing with variability. Discussed briefly on pages 287-288 of TR, but beyond the scope of this course.

V. General Cautions and Suggestions

A. Demographic modeling, while the most powerful of the monitoring methods for certain species, is inappropriate for other species (**Figure 12.13**).

CHARACTERISTICS OF:	
Species Easily Monitored by Demographic Techniques:	**Species Not Easily Monitored by Demographic Techniques:**
-lack seedbank	-long-lived seedbank
-lack vegetative reproduction, or -vegetative daughters easily traced to parents	-dense vegetative reproduction
-moderate life-span (3-7 years)	-very short (annual) or very long life-span
-regular reproduction	-episodic reproduction
-single-stem or trunk morphology	-multiple stem morphology -mat-like morphology
-low densities	-high densities
-populations small enough to census	-large populations on heterogeneous habitats

Figure 12.13

B. Suggestions for success:
   1. Allocate adequate resources.
   2. Solicit extensive review.
   3. Conduct a 2-year pilot study.
   4. Administer contracts closely.

VI. Age/Stage Class Investigations

A. Monitoring that assesses a single or several stages often has increased biological interpretability over simple measures of cover, frequency, or density.
   1. For example, for woody riparian species you might want to focus on recruitment.
   2. Your monitoring would then be directed to determining whether the seedling and juvenile stages are present and healthy.

B. Must choose the appropriate stage or you might miss important changes – can use ecological models to help.

VII. Demographic Structure and Changes in Demographic Structure

A. This snapshot-in-time measure of demographic structure can provide useful insights into the viability of a population.
   1. Monitoring the change in demographic structure is often more sensitive and more easily interpreted than changes in density.
   2. Density can remain constant in a population that is experiencing a negative change in demographic structure.

B. Problems.
   1. Technique not applicable to plants with no consistent counting units.
   2. Can be far more time-consuming than simple density counts, especially when classing each individual is difficult.
   3. Sampling design more complex because a design must consider variability in numbers and distribution of each stage class.

VIII. Count-based Population Viability Assessments

A. Morris et al. (1999) and Morris and Doak (2002) describe the procedure used to perform a population viability assessment using a time series of count-based data (i.e., population size).
   1. Based on the method described by Dennis et al. (1991).
   2. Counts are usually based on a census.
   3. Counts can be of a segment of the entire population (e.g., plants that are actually flowering) as long as the segment is a relatively constant fraction of the whole.
   4. Morris et al. (1999) provide an example of a count-based PVA on 11 years of count data for Knowlton's cactus in New Mexico.

B. Problems.
   1. Requires at least 10 years of count data (Morris et al. 1999), though the years do not have to be consecutive.
   2. Analysis is much more difficult if the population or population segment being counted varies greatly with environmental factors (e.g., annual plants), though Morris and Doak (2002) give a procedure to incorporate this variability into the analysis. However, the results of a PVA on such a species may be suspect.
   3. Method may not be very accurate (see Reed et al. 2002).
   4. Approach is not as powerful as the demographic-based approach.

5. Model assumes that there is no observation or sampling error though there are ways to incorporate this into the model if there is a good estimate of it.

References

(See Chapter pp. 291-295 of the TR and the paper by Crone et al. (2011) for many more references. The ones listed below are either cited in the outline above or are more recent than the references in the TR.)

Bierzychudek, P. 1982. The demography of jack-in-the-pulpit, a forest perennial that changes sex. Ecological Monographs 52:335-351. Provided on CD.

Bierzychudek, P. 1999. Looking backwards: assessing the projections of a transition matrix model. Ecological Applications 9:1278-1287. Provided on CD.

Crone, E. E. et al. 2011. How do plant ecologists use matrix population models? Ecology Letters 14: 1-8. There are two companion Excel workbooks, one showing citations for all published studies examined in the paper and another showing how these studies were classified. The first Excel files include most of the papers ever published using matrix population models and other demographic techniques and is therefore a valuable place to start when contemplating a demographic approach to monitoring. Paper and Excel workbooks provided on CD.

Dennis, B., P. L. Munholland, and J. M. Scott. 1991. Estimation of growth and extinction parameters for endangered species. Ecological Monographs 61:115-143.

Doak, D. F., D. Thomson, and E. S. Jules. 2002. Population viability analysis for plants: understanding the demographic consequences of seed banks for population health. Chapter 15 in: S. R. Beissinger and D. R. McCullough. Population Viability Analysis. University of Chicago Press, Chicago, IL, pp. 312-337.

Menges, E.S. 2000. Population viability analysis in plants: challenges and opportunities. Trends in Ecology and Evolution 15:51-56. Provided on CD.

Morris, W., D. Doak, M. Groom, P. Kareiva, J. Fieberg, L. Gerber, P. Murphy, and D. Thomson. 1999. A practical handbook for population viability analysis. The Nature Conservancy, Washington, DC. Provided on CD.

Morris, W. F., and D. F. Doak. 2002. Quantitative conservation biology: theory and practice of population viability analysis. Sinauer Associates Inc., Sunderland, MA.

Reed, J. M., L. S. Mills, J. B. Dunning, Jr., E. S. Menges, K. S. McKelvey, R. Frye, S. R. Beissinger, M-C Anstett, and P. Miller. 2002. Emerging issues in population viability analysis. Conservation Biology 16:7-19. Provided on CD.

Solbrig, O. T. 1980. Demography and evolution in plant populations. University of California Press, Berkeley, CA.